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Estimation of the Fecundity of Pacific Cod (Gadus macrocephalus)

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ESTIMATION OF THE FECUNDITY OF PACIFIC COD (*GADUS MACROCEPHALUS*)

by

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ABSTRACT

Foucher, R. P. and A. V. Tyler. 1990. Estimation of the fecundity of Pacific cod (*Gadus macrocephalus*). Can. MS Rep. Fish. Aquat. Sci. 2088: 49 p.

Fecundity was determined for 350 Pacific cod from the west coast of Vancouver Island (LaPerouse area) and Hecate Strait over five years, 1986-90. There was little variation by year, geographic area or temperature and no significant difference from similar work done about 25 years earlier. Counts ranged from 0.228 to 5.67 million oocytes for fish ranging in length from 40 to 89 cm. Relationships were determined for fecundity on fish length and weight. The process of hydration was found to greatly affect the number of oocytes per mg, and the percent dry weight vs fish length and ovary weight vs fish weight relationships. The generally smaller oocytes found in smaller fish suggests that either smaller fish release smaller oocytes, or that they possibly spawn later, allowing more time for oocyte growth.

RÉSUMÉ

Foucher, R. P. and A. V. Tyler. 1990. Estimation of the fecundity of Pacific cod (*Gadus macrocephalus*). Can. MS Rep. Fish. Aquat. Sci. 2088: 49 p.

La fécondité de 350 morues du Pacifique de la côte ouest de l'Ile de Vancouver (zone de la Pérouse) et du détroit d'Hécate a été déterminée sur une période de cinq ans, soit entre 1986 et 1990. On a enregistré peu de variation par année, zone géographique ou température et aucune différence importante n'a été observée à partir de travaux similaires effectués il y a environ 25 ans. Les dénombrements d'ovocytes s'établissaient entre 0,228 et 5,67 millions pour des poissons dont la longueur était comprise entre 40 et 89 cm. Les rapports ont été déterminés pour la fécondité par rapport à la longueur et au poinds du puisson. On a constaté que le processus d'Hydratation modifie énormément le nombre d'ovocytes par mg, et les rapports entre le pourcentage de poids sec par rapport à la longueur du poisson, et le poids des ovaires par rapport au poids du puisson. Les ovocytes en général plus tetits chez les puissons de petite taille semblent indiuer que les poissons de petite taille libèrent des ovocytes plus petits, ou qu'ils frayent plus tard, ce qui permet aux ovocytes de se développer davantage.

INTRODUCTION

The determination of fecundity in both the Hecate Strait and west coast of Vancouver Island (LaPerouse area) was carried out as part of an investigation of the reproductive biology of Pacific cod (Gadus macrocephalus). The annual cycle of ovarian development is being examined through histological techniques and will be reported separately. Determination of fecundity has been done previously for Hecate Strait (Thomson 1962) and was, in that paper, compared to fecundity estimates from other areas of the North Pacific Ocean. One limitation of that study was that individual fish weights were not taken with the ovary samples.

This project covered five spawning seasons (1986-90) and included two widely-separated regions within British Columbia waters for 1988. This broad scope allowed comparisons by both year and geographic region. The relationship to temperature was also investigated.

MATERIALS AND METHODS

Sampling information for the six samples used in this study is provided in Table 1. The first sample was collected aboard the G.B. REED during January-February 1986 (Foucher et al. 1988) with fish coming from a variety of locations in Hecate Strait. The second sample was collected in northern Hecate Strait aboard the NUCLEUS chartered for a trip during January 1987 (Foucher et al. 1987). The third sample, from northwestern Hecate Strait, was collected from a commercial landing of the OCEAN FISHER to a fish plant in Prince Rupert. The fourth sample was from Amphitrite Bank off the southwest coast of Vancouver Island. It was sampled in a Nanaimo fish plant after the fish were landed by the DANNY & DAVID and trucked from Ucluelet. The fifth sample came from a research cruise aboard the BLUE WATERS during January-February 1989 (Foucher et al. 1989). Fish were sampled from three grounds in Hecate Strait with the majority being from White Rocks. The sixth sample, caught on Amphitrite Bank, was from a charter landing by the GAIL BERNICE to a fish plant in Ucluelet on January 29, 1990

A length-stratified sampling procedure was used after the first sample to ensure that samples were spread throughout the anticipated length range. The target sampling level was approximately 10 fish per 5-cm interval. All fish were measured for fork length to the nearest cm. Both ovaries were stored in 1-l jars. Whole fish weights (less stomach contents) and ovary weights were taken for the DANNY & DAVID, BLUE WATERS and GAIL BERNICE samples.

The method of fixation varied somewhat among samples. For the G.B. REED samples, Gilson's solution (equal parts

chloroform, ethanol and glacial acetic acid) was used which hardened the oocytes very well. They were transferred to 30% ethanol after 15 months but remained difficult to separate. The other samples were fixed in 70% ethanol and later (except for the last three samples) transferred to 30% ethanol. The ethanol fixed the samples adequately, providing sufficient volume was used. It also promoted separation of the oocytes from each other and from other ovarian tissue. When the last few samples were collected, the ovaries were sliced up extensively and immediately shaken vigorously in 70% ethanol. This seemed to liberate the oocytes very well from the ovarian tissue and the ethanol solution was not later diluted.

The procedure for determining fecundity involved separating the oocytes from any ovarian tissue and small oocytes by washing through sieves and manual removal of larger pieces. Each sample was then vacuum-filtered in a Buchner funnel to a constant drip rate and weighed. This weight is referred to in the results as the oocyte sample weight. From this, four subsamples, of about 500 oocytes each, were weighed and counted. One subsample was randomly selected for each fish and recounted as a check on counting precision. Any small, undeveloped oocytes encountered were not counted. For the NUCLEUS sample only, the four subsamples were combined and dried to a constant weight.

Fecundity was determined by proportion using the four subsample counts and weights combined and the total sample weight:

$$N = W \left(\sum_{i=1}^{4} n_i \; / \sum_{i=1}^{4} w_i, \right)$$

where N = estimated fecundity,
W = weight of total sample,
n = weight of subsample i,
w = number of oocytes in subsample i,
and i = subsample number.

The following relationships were examined:

Fecundity	vs length
Fecundity	vs oocyte sample weight
Oocytes/mg	vs length
Dry weight	vs wet weight[a]
Fish weight	vs fish length[b]
Ovary weight	vs fish weight[b]
Ovary weight	vs oocyte sample weight[b]
Fecundity	vs fish wt. (less ovary)[b]

[a] NUCLEUS only
[b] DANNY & DAVID, BLUE WATERS and GAIL BERNICE

Oocyte counts were carried out by contract. The NUCLEUS and BLUE WATERS samples were processed by Archipelago Marine Research (Victoria, B.C.) and the other samples by Aquametrix Research Ltd. (Sidney, B.C.).

Temperature data were collected during the G.B. REED, and NUCLEUS cruises using expendable bathythermographs. During the BLUE WATERS cruise surface temperatures only were collected due to equipment failure. Temperature data from lighthouse stations is also used.

RESULTS

Fecundity vs length

Curves (Fecundity = a Length^b) were fit to each sample by using a log-log regression:

$$\text{Log } F = a + b(\log L)$$

where F = millions of oocytes,
and L = length in cm.

The resulting formulas were (including Thomson's (1962) results):

Sample	Sample size	Length range(cm)	Fecundity (millions)	Parameters a	b	r
G.B. REED	53	53-83	0.785-4.57	-6.513	3.719	0.90
NUCLEUS	106	48-89	0.384-5.67	-5.999	3.450	0.89
OCEAN FISHER	41	47-68	0.477-2.55	-6.727	3.864	0.91
DANNY & DAVID	40	47-80	0.581-2.75	-5.667	3.280	0.91
BLUE WATERS	66	44-82	0.505-5.48	-6.280	3.593	0.94
GAIL BERNICE	44	55-78	0.899-4.08	-5.029	2.904	0.81
Thomson 1962	46	40-88	0.228-3.33	-6.412	3.647	0.94

The six data sets from this study, each with their fitted curve, are shown in Figure 1a-f. The fecundity-length relationships for all six samples from this study are similar; but the lowest slopes and intercepts were from the west coast of Vancouver Island (DANNY & DAVID, GAIL BERNICE). Also, the sample

of Thomson (1962) showed lower fecundity than did our Hecate Strait samples (Figure 2).

The slope of each log-log regression was compared to each of the others to see where any differences might lie. Of 21 comparisons, analysis of covariance identified four cases (at a 90% confidence level) where the slopes were significantly different. These were:

GAIL BERNICE - BLUE WATERS - $F = 3.66$ (d.f. = 1,105)
GAIL BERNICE - G. B. REED - $F = 4.03$ (d.f. = 1,92)
GAIL BERNICE - OCEAN FISHER - $F = 4.86$ (d.f. = 1,80)
GAIL BERNICE - Thomson 1962 - $F = 3.76$ (d.f. = 1,85)

The GAIL BERNICE sample was from the west coast of Vancouver Island, whereas all of the others were from Hecate Strait, indicating a possible regional variation. Data were then combined by region to describe the relationship for each:

West coast
Vancouver Island: $\log F = -5.074 + 2.934(\log L)$; N= 83; r=0.90;
Hecate Strait: $\log F = -6.156 + 3.531(\log L)$; N=272; r=0.92.

For the whole coast combined the relationship was:

$\log F = -5.890 + 3.386(\log L)$; N=355; r=0.91.

Fecundity vs oocyte sample weight

The comparison of fecundity to oocyte sample weight (the weight of the oocytes after separation from ovarian tissue and just prior to counting) for each sample produced the following relationships:

$F = 0.829 + 0.00426\ C$;	$r = 0.64$	G. B. REED (Figure 3a)
$F = 1.18 + 0.00395\ C$;	$r = 0.72$	NUCLEUS (Figure 3b)
$F = 0.504 + 0.00277\ C$;	$r = 0.88$	OCEAN FISHER (Figure 3c)
$F = 0.718 + 0.00177\ C$;	$r = 0.80$	DANNY & DAVID (Figure 3d)
$F = 0.569 + 0.00350\ C$;	$r = 0.85$	BLUE WATERS (Figure 3e)
$F = 0.470 + 0.00358\ C$;	$r = 0.87$	GAIL BERNICE (Figure 3f)

It is interesting to note variations from the calculated fits (Figure 3a-f). Points significantly to the left of the line (Figure 3a) represent fish that are lagging in their development. Points to the right represent fish whose oocytes have begun to hydrate, rapidly increasing in size and weight by taking in water. Especially, note one fish in the DANNY & DAVID sample (Figure 3d) with an oocyte sample weight of over 1500 g for about 2.7 million oocytes. At sampling, 4 jars were required to contain the very large ovaries containing translucent oocytes. The degree to which individual points vary from the fitted line

indicates the degree of variation in development.

When the fitted lines for these six samples are compared (Figure 4) it can be seen that fish from the DANNY & DAVID sample were likely the closest to being in spawning condition with a greater weight at the same fecundity.

Oocytes/mg vs length

With only a few exceptions in the samples, the number of oocytes/mg seems to have a lower limit of about 3-4 (Figures 5a-f). This could correspond to the weight of oocytes shortly before the process of hydration. Cases with fewer than 3 oocytes/mg (see Figure 5d) correspond to those fish in which hydration has begun as noted in the preceding section. In a number of ovaries, especially in the NUCLEUS sample from northern Hecate Strait, the number of oocytes/mg was much higher, reflecting their less advanced ripeness. This was especially the case for smaller fish suggesting that these fish spawn later than larger fish and/or produce smaller oocytes.

Dry weight vs wet weight

For the NUCLEUS sample only, dry weights were determined for the oocytes counted from each ovary. There was a direct relationship between dry weight and wet weight (Figure 6):

$$D = -4.32 + 0.237\ W; \quad r=0.94$$

where D = dry weight in mg of 4 subsamples combined,
and W = wet weight in mg of 4 subsamples combined.

Most of the outliers were to the right of the fitted line. These are likely ovaries which are at a more advanced stage of development. Shortly before release the oocytes take on water and rapidly increase their volume. This would increase wet weight but not dry weight and produce the observed results.

Fish weight vs fish length

For the three samples for which female weights were collected the length-weight relationships were:

$W = 7.00 \times 10^{-6}\ L^{3.1614}$, r = 0.98 DANNY & DAVID (Figure 7a)
$W = 3.86 \times 10^{-6}\ L^{3.2786}$, r = 0.99 BLUE WATERS (Figure 7b)
$W = 5.24 \times 10^{-6}\ L^{3.2138}$, r = 0.97 GAIL BERNICE (Figure 7c)

where W = round fish weight in kg,
and L = fork length in cm.

This relationship described by Westrheim (1977) was:

$$W = 4.998 \times 10^{-6} L^{3.2117}$$

which applied to Pacific cod also collected in February but with sexes combined and from a combination of west coast of Vancouver Island and Hecate Strait. In each case fish weights were round weights less the stomach contents but including the ovary.

Ovary weight vs fish weight

The relationships of ovary weight to fish weight (excluding weight of the ovary) appeared to be linear:

O = -248 + 311 F; r = 0.84 DANNY & DAVID (Figure 8a)
O = -182 + 227 F; r = 0.86 BLUE WATERS (Figure 8b)
O = -239 + 223 F; r = 0.81 GAIL BERNICE (Figure 8c)

where O = ovary weight in g,
and F = round fish weight (excluding the ovary) in kg.

The few points that were significantly above the line corresponded to fish whose oocytes had likely begun the process of hydration. As has been noted, this was especially the case for the fish having the largest ovary weight in the DANNY & DAVID sample (Figure 8a).

Oocyte sample weight vs ovary weight

The ovary weight here is the weight of the ovary weighed in its fresh state immediately upon removal from the fish. The oocyte sample weight is the weight of the sample just prior to the counting process. This is after the oocytes have been separated from ovarian tissue. The difference (vertical distance) between a line fitted to the points and a line representing equal weights on both axes (Figure 9) represents the weight of tissues lost in the process of separating the oocytes from the ovarian tissue plus any possible change in weight of tissues due to fixation. The relationships found are:

C = -5.40 + 0.804 V; r = 0.99 DANNY&DAVID (Figure 9a)
C = 16.2 + 0.706 V; r = 0.99 BLUE WATERS (Figure 9b)
C = 50.5 + 0.550 V; r = 0.98 GAIL BERNICE(Figure 9c)

where C = oocyte weight in g,
and V = ovary weight in g.

Fecundity vs fish weight

The relationships between fecundity and fish weight were:

F = -0.037 + 0.619 W; r = 0.92 DANNY&DAVID (Figure 10a)

$F = -0.416 + 0.741\ W$; $r = 0.90$ BLUE WATERS (Figure 10b)
$F = -0.071 + 0.500\ W$; $r = 0.77$ GAIL BERNICE(Figure 10c)

where F = fecundity in millions of oocytes,
and W = fish weight in kg with ovaries and stomach contents removed.

Fish from Hecate Strait (BLUE WATERS) had a greater fecundity-at-size (weight) than did those from the south west coast of Vancouver Island (DANNY & DAVID and GAIL BERNICE).

The point furthest to the right of the curve in the DANNY & DAVID sample (Figure 10a) represents an 80-cm cod which had a low ratio of oocyte sample weight to fresh ovary weight (Figure 9a, point furthest below fitted line, ovary weight = 1151g). This indicates that a high proportion of the ovary weight was tissue other than oocytes. This fish may have had lessened ovarian activity due to senescence.

Temperature

Temperature data available for comparison between samples is presented in Table 2. Although the temperatures are for sea surface, mixing is such during the first quarter of the year that surface readings are a good indication of the temperature at the depths at which cod spawn. There is no apparent relationship between temperature and fecundity within a region. Temperatures are lower for Hecate Strait, where fecundity is higher, but more data would be required to demonstrate a relationship.

Senescent ovaries

Of the fish sampled from the Gail Bernice for which maturity stage was noted, 9, 88 and 3% were in stages 3, 4 and 5 respectively. An additional 7 fish appeared to be resting but were unusual in that the ovary was very hard and shrivelled with a very black exterior. These made up 14% of the fish examined and were not included in the fecundity sample.

DISCUSSION

There was little variation in fecundity-length relationship between the six samples. All Hecate Strait samples collected in this study showed a higher fecundity at length than the results of Thomson (1962). This may be related to the effect of the fishery on the population over the 25 years since his study. It is possible that the stock size is lower now than in its nearly unutilized state. At a low stock size, each fish would have an increased food supply and be capable of producing more eggs to maintain the population. Fish in Hecate Strait showed slightly higher fecundity-at-size than did those from south west Vancouver Island, where fish were measured as either length or weight.

ACKNOWLEDGMENTS

Ivan Winther collected the OCEAN FISHER sample. Patricia Summers did much of the work to separate oocytes from the ovarian tissue. Dave Burt assisted with collection of the GAIL BERNICE sample. Other individuals were involved in collecting samples during research cruises. They are listed as authors of the corresponding reports. J. Fargo and C. Hand reviewed the manuscript.

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Table 1. Sampling information for Pacific cod used for analysis of fecundity.

Vessel	Date	Area	Number sampled
G.B. REED	Jan 27-Feb 18 1986	Hecate Strait	53
NUCLEUS	January 5-17 1987	Hecate Strait	106
OCEAN FISHER	January 26 1988	Hecate Strait	41
DANNY & DAVID	February 5 1988	W. coast Vancouver Is.	40
BLUE WATERS	Jan 30-Feb 9 1989	Hecate Strait	66
GAIL BERNICE	January 29 1990	W. coast Vancouver Is.	43[a]
Total			339

[a] One fish rejected from sample.

Table 2. Temperature data (sea surface ^{0}C) corresponding to time and area of fecundity samples.

Sample	Date		Temperature (^{0}C) Cruise	Lighthouse[a] Jan	Lighthouse[a] Feb
G.B. REED[a]	Jan 27-Feb 18	1986	5.8-7.0	6.4	5.9[b]
NUCLEUS[c]	January 5-17	1987	8.7-8.8		7.8[b]
OCEAN FISHER	January 26	1988	-		7.4[b]
DANNY & DAVID	February 5	1988	-	8.2	7.9[d]
BLUE WATERS[e]	Jan 30-Feb 9	1989	5.4-6.1	6.5	5.5[b]
GAIL BERNICE	January 29	1990	-	8.8	7.6[d]
Thomson 1962	February	1962	-		5.8[b]

[a]Range for 6 of 22 tows sampled for fecundity.
[b]Bonilla Island lighthouse.
[c]Range for 3 of 4 tows sampled for fecundity.
[d]Amphitrite Point lighthouse.
[e]Range for 3 of 6 tows sampled for fecundity.

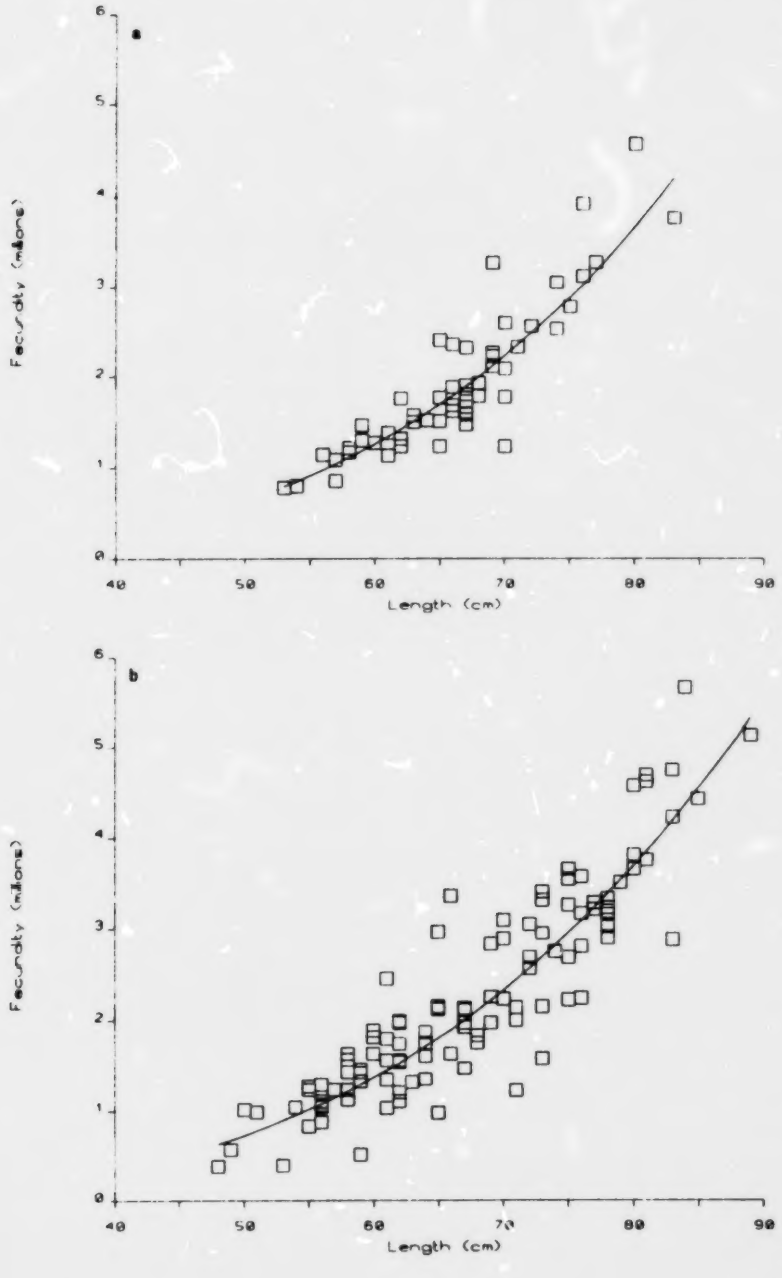


Figure 1. Pacific cod fecundity in millions (F) vs length in cm (L) by sample.

a) G.B. REED, Hecate Strait, January 27-February 18, 1986.
log F = -6.513 + 3.719(log L); N = 53.

b) NUCLEUS, Hecate Strait, January 5-17, 1987.
log F = -5.999 + 3.450(log L); N = 106.

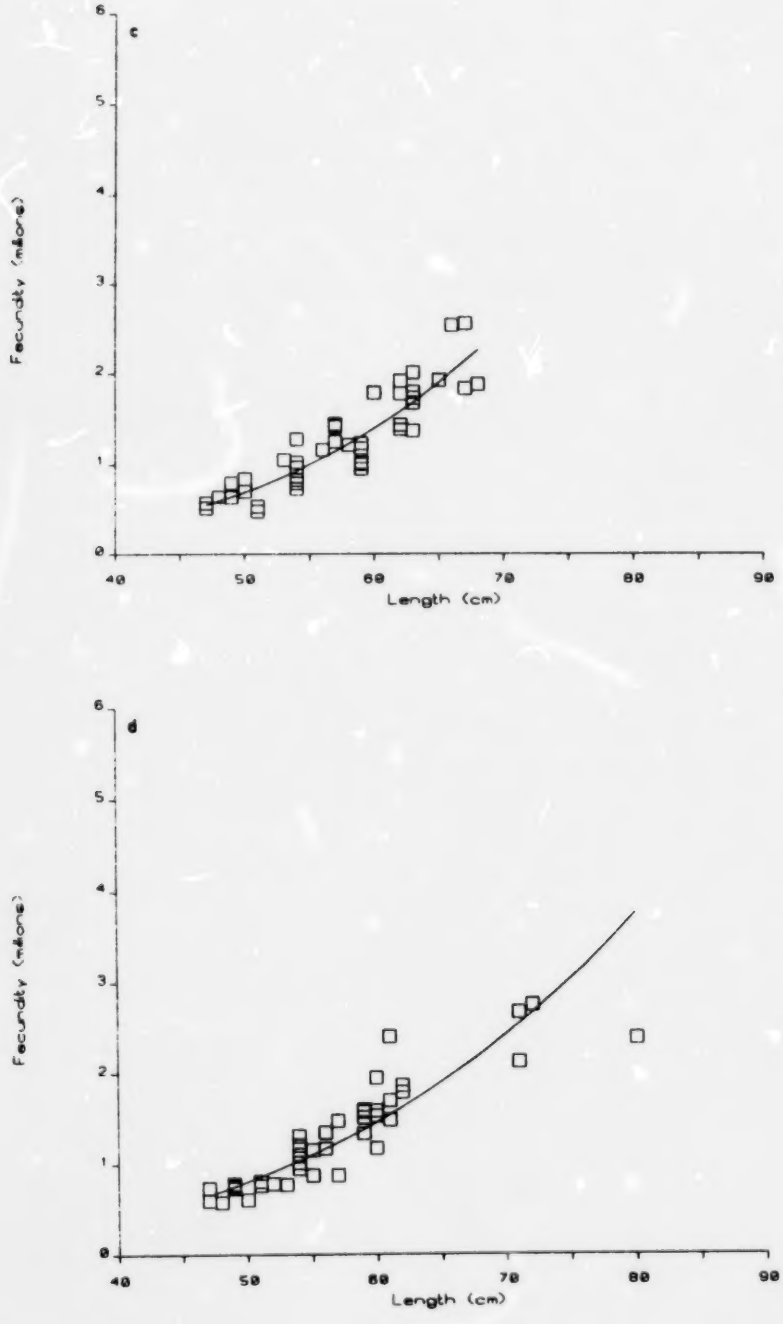


Figure 1. Continued.
c) OCEAN FISHER, Hecate Strait, January 26, 1988.
log F = -6.727 + 3.864(log L); N = 41.
d) DANNY & DAVID, west coast Vancouver Is., February 5, 1988.
log F = -5.667 + 3.280(log L); N = 40.

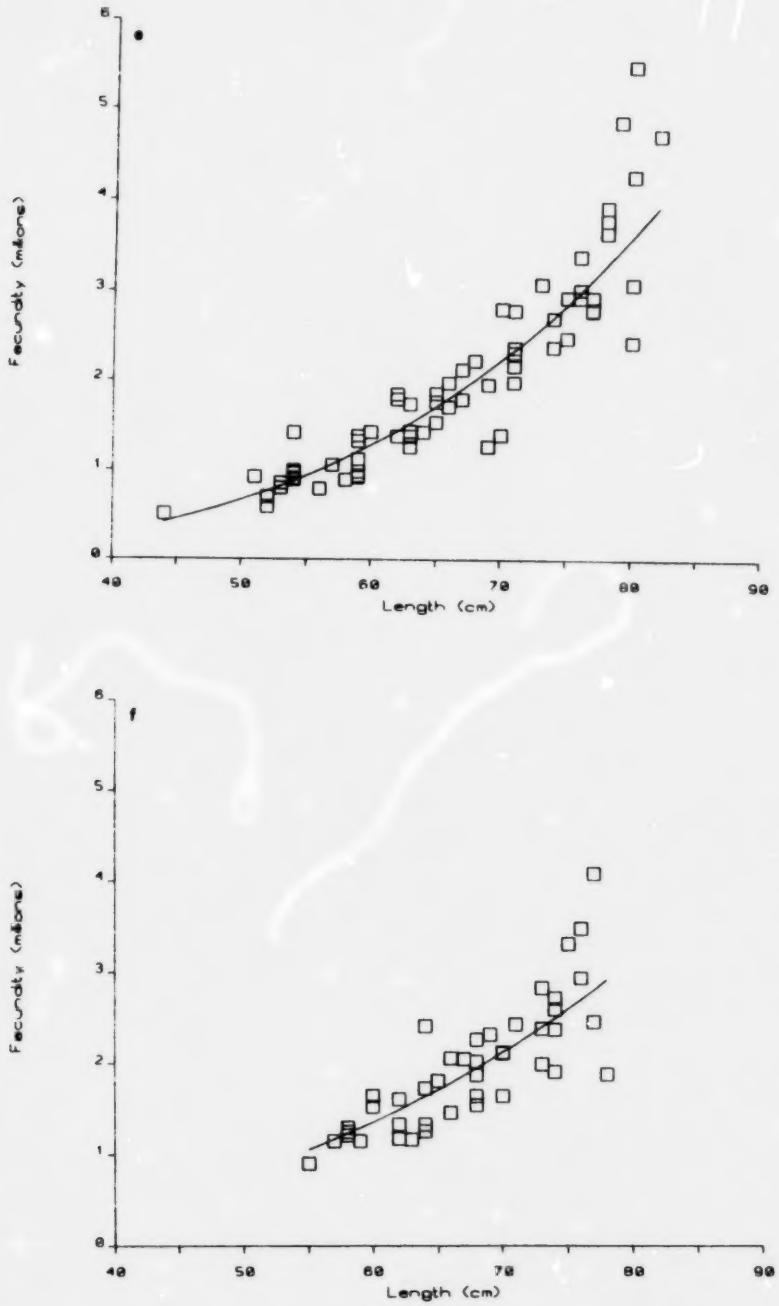


Figure 1. Continued.
e) BLUE WATERS, Hecate Strait, January 30-February 9, 1989. log F = -6.280 + 3.593(log L); N = 66.
f) GAIL BERNICE, west coast Vancouver Is., January 29, 1990. log F = -5.029 + 2.904(log L). N = 43.

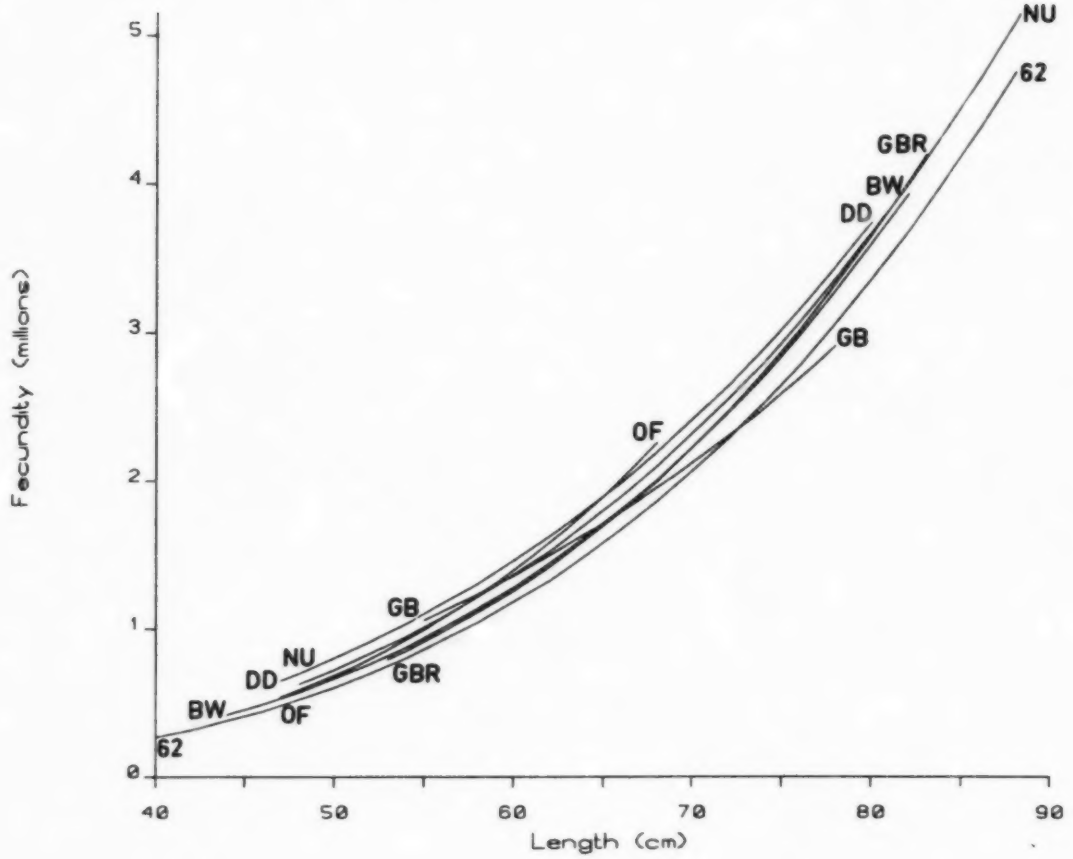


Fig. 2. Pacific cod fecundity in millions (F) vs length in cm (L) by sample.

BW = BLUE WATERS: log F = -6.280 + 3.953(log L);
DD = DANNY & DAVID: log F = -5.667 + 3.280(log L);
GB = GAIL BERNICE: log F = -5.029 + 2.904(log L);
GBR= G.B. REED: log F = -6.513 + 3.719(log L);
NU = NUCLEUS: log F = -5.999 + 3.450(log L);
OF = OCEAN FISHER: log F = -6.727 + 3.864(log L);
62 = THOMSON 62: log F = -6.412 + 3.647(log L).

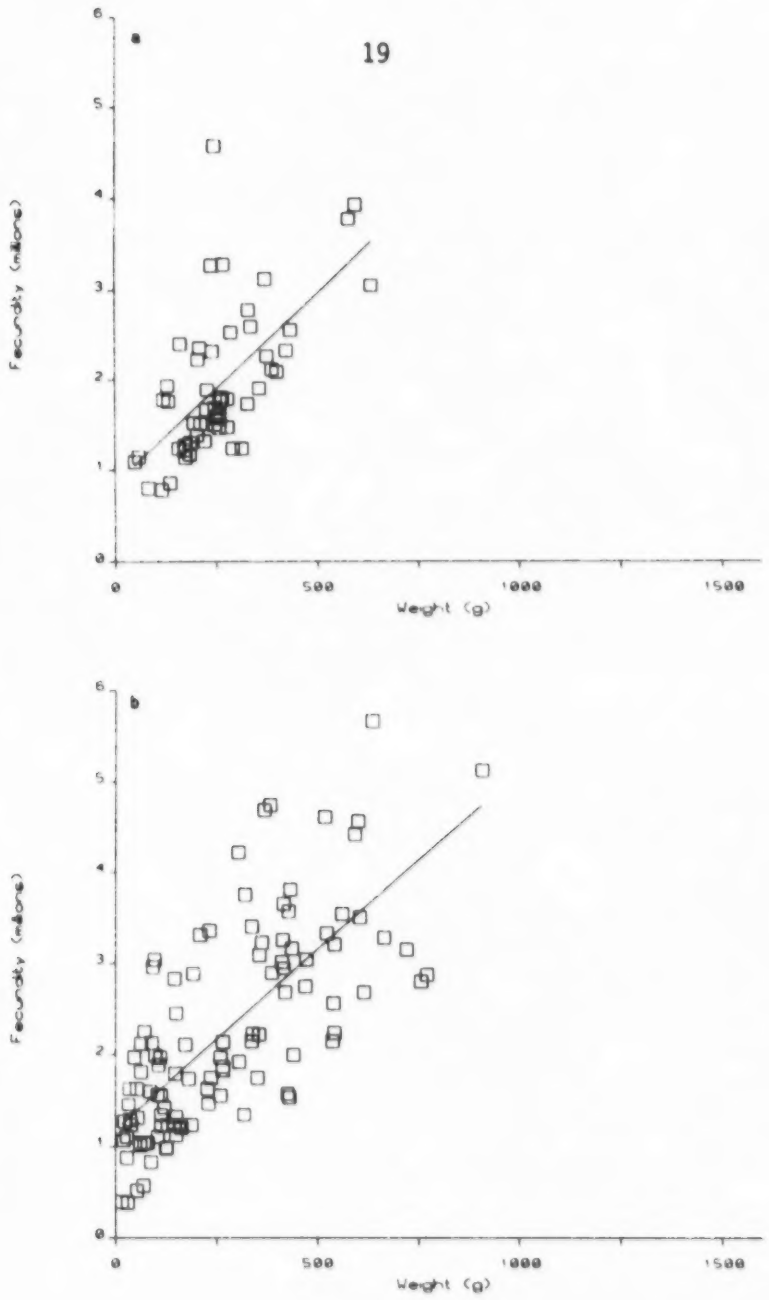
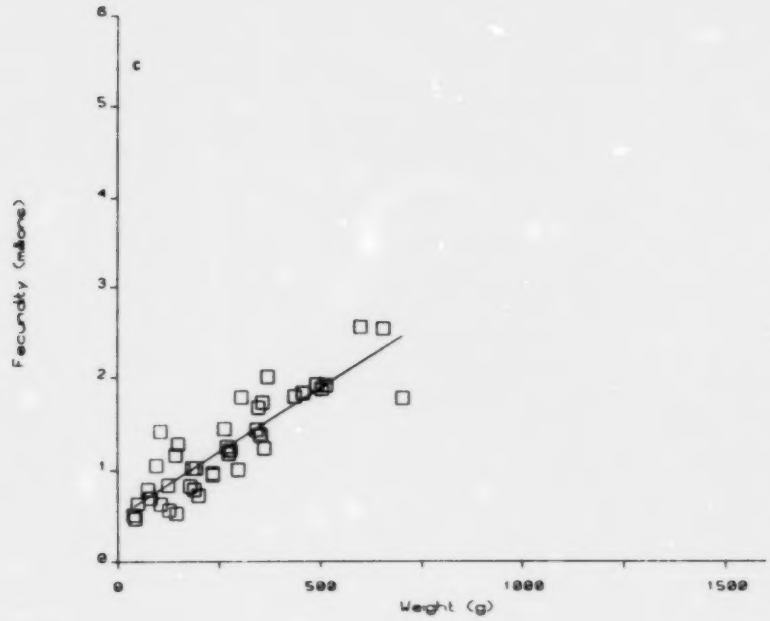


Figure 3. Pacific cod fecundity in millions (F) vs oocyte sample weight (wet weight of all separated, processed oocytes) in g (C) by sample.

a) G.B. REED, Hecate Strait, January 27-February 18, 1986.
F = 0.829 + 0.00426 C, r = 0.638;
b) NUCLEUS, Hecate Strait, January 5-17, 1987.
F = 1.18 + 0.00395 C, r = 0.723;



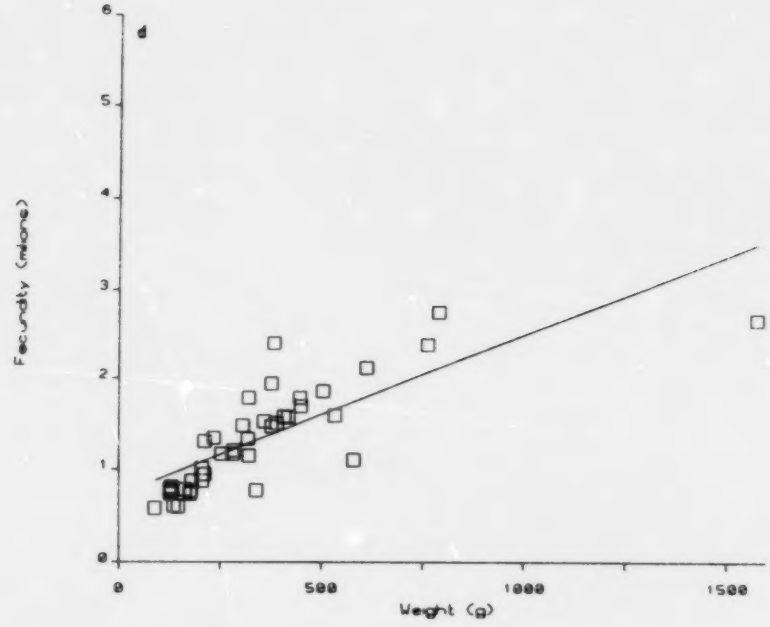


Figure 3. Continued.
c) OCEAN FISHER, Hecate Strait, January 26, 1988.
F = 0.504 + 0.00277 C, r = 0.877;
d) DANNY & DAVID, west coast Vancouver Is., February 5, 1988.
F = 0.718 + 0.00177 C, r = 0.797;

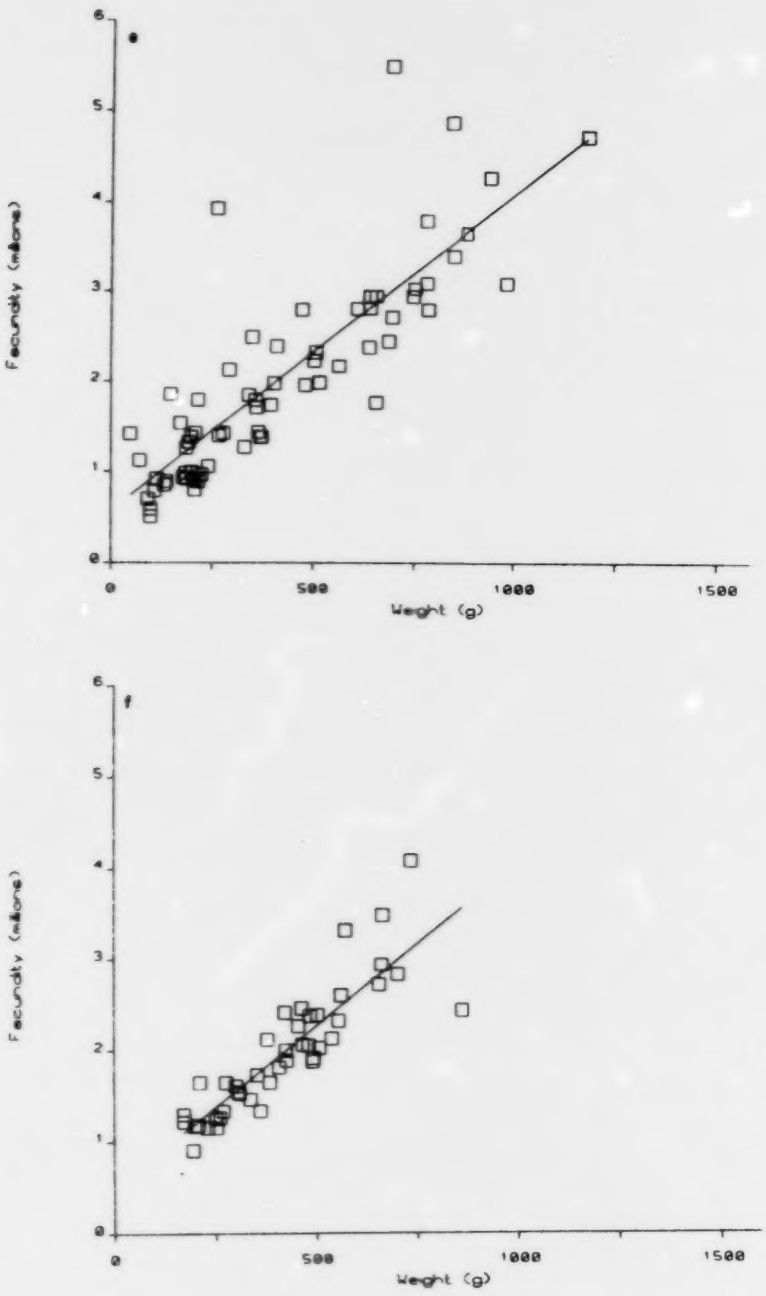


Figure 3. Continued.
e) BLUE WATERS, Hecate Strait, January 30-February 9, 1989. F = 0.569 + 0.00350 C, r = 0.847;
f) GAIL BERNICE, west coast Vancouver Is., January 29, 1990. F = 0.470 + 0.00358 C, r = 0.869;

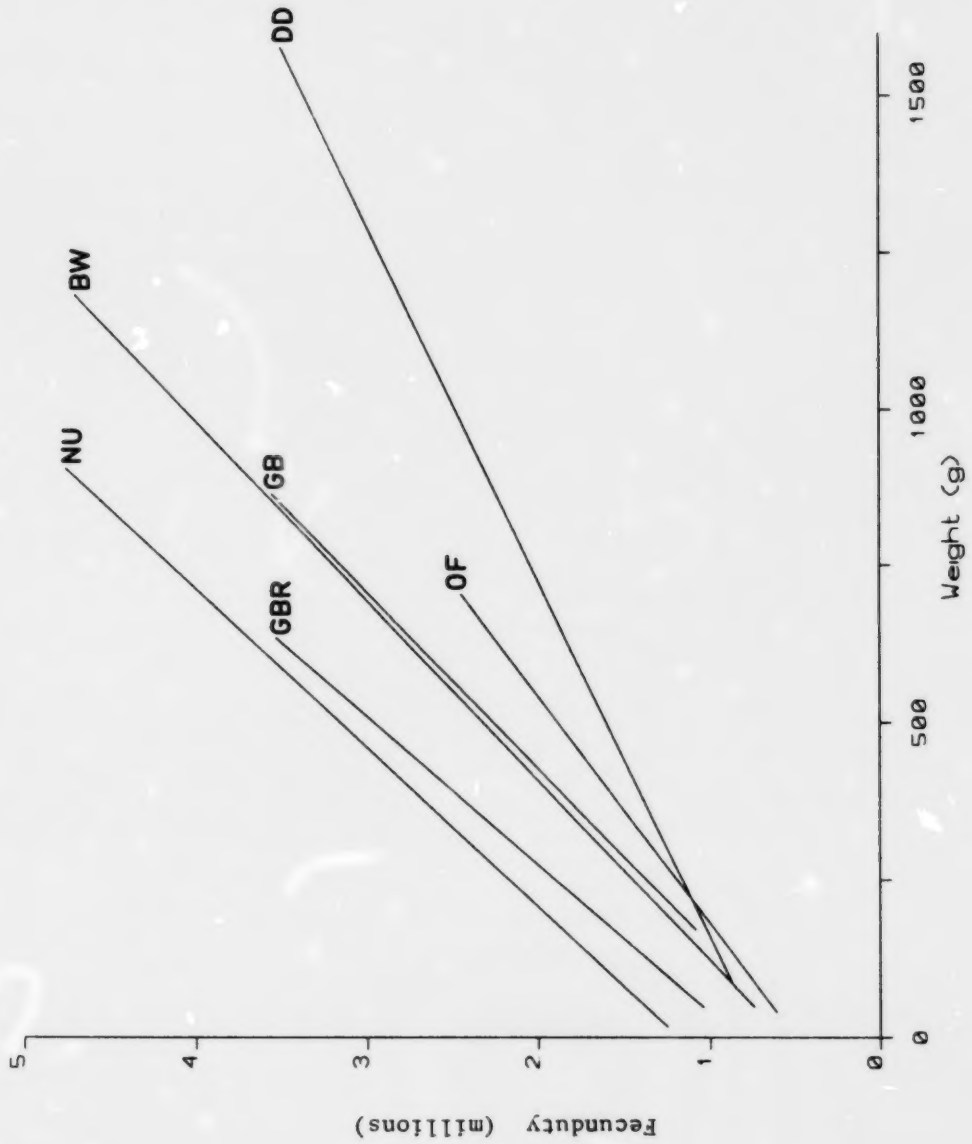


Figure 4. Pacific cod fecundity in millions (F) vs oocyte sample weight in g (C) for all samples.

BW = BLUE WATERS: F = 0.569 + 0.00350 C;
DD = DANNY & DAVID: F = 0.718 + 0.00177 C;
GB = GAIL BERNICE: F = 0.470 + 0.00358 C.
GBR = G.B. REED: F = 0.829 + 0.00426 C;
NU = NUCLEUS: F = 1.18 + 0.00395 C;
OF = OCEAN FISHER: F = 0.504 + 0.00277 C;

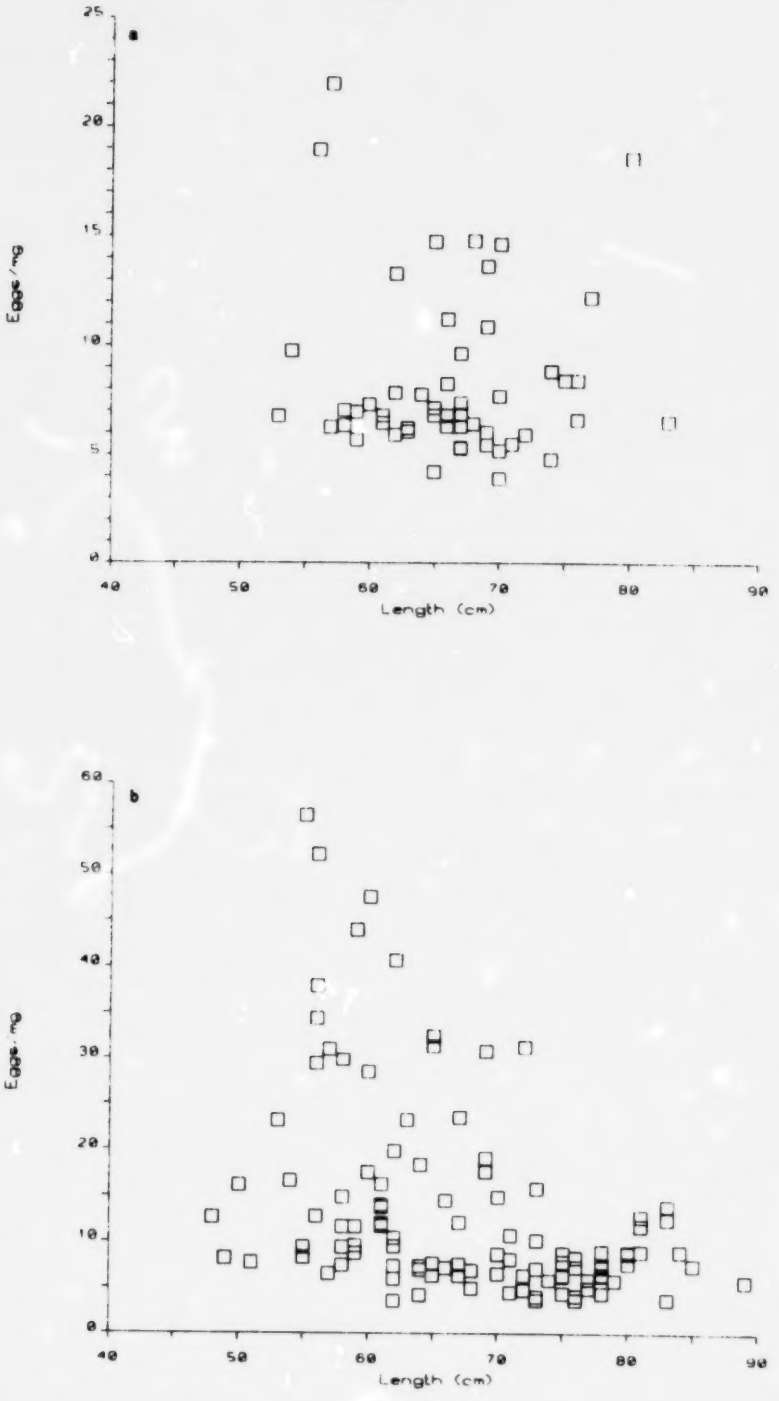


Figure 5. Pacific cod number of oocytes/mg vs length, by sample.
a) G.B. REED, Hecate Strait, January 27-February 18, 1986.
b) NUCLEUS, Hecate Strait, January 5-17, 1987.

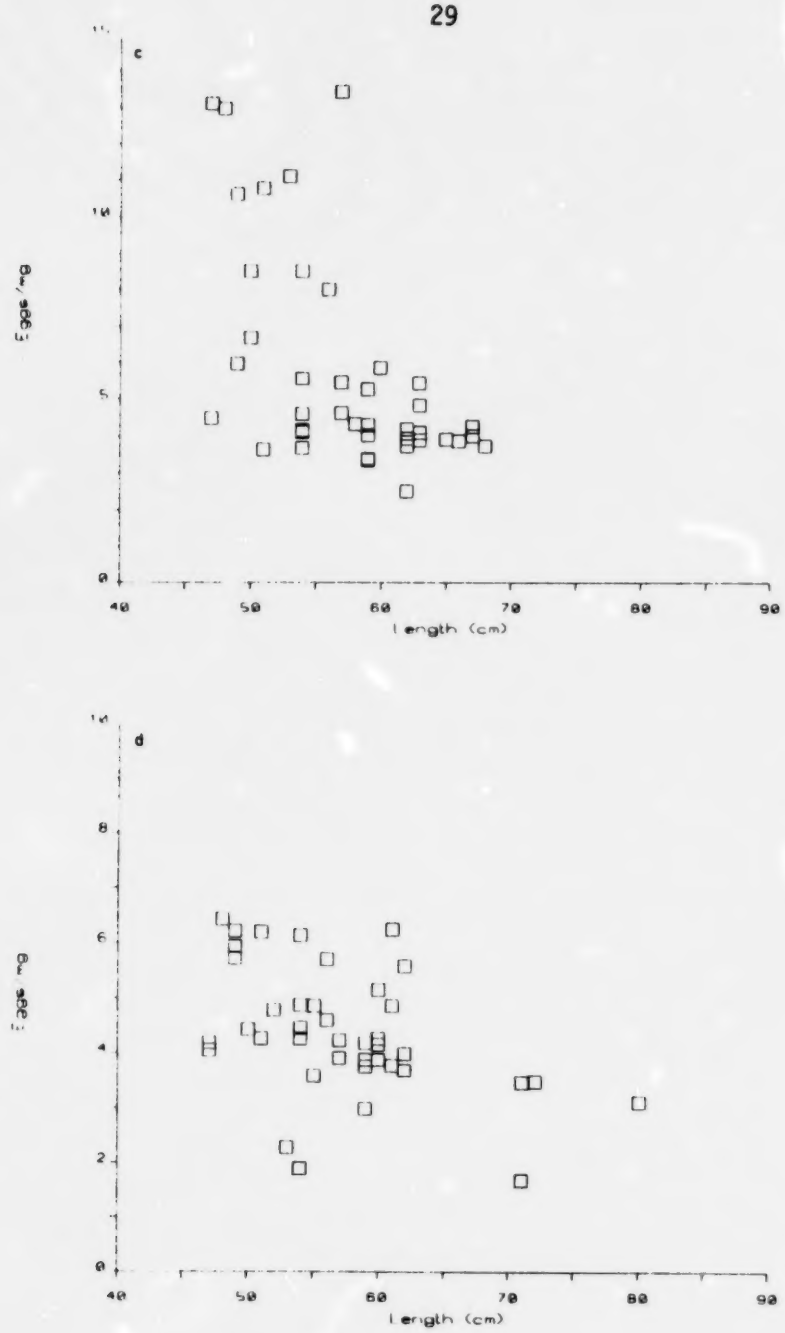


Figure 5. Continued.
c) OCEAN FISHER, Hecate Strait, January 26, 1988.
d) DANNY & DAVID, west coast Vancouver Is., February 5, 1988.

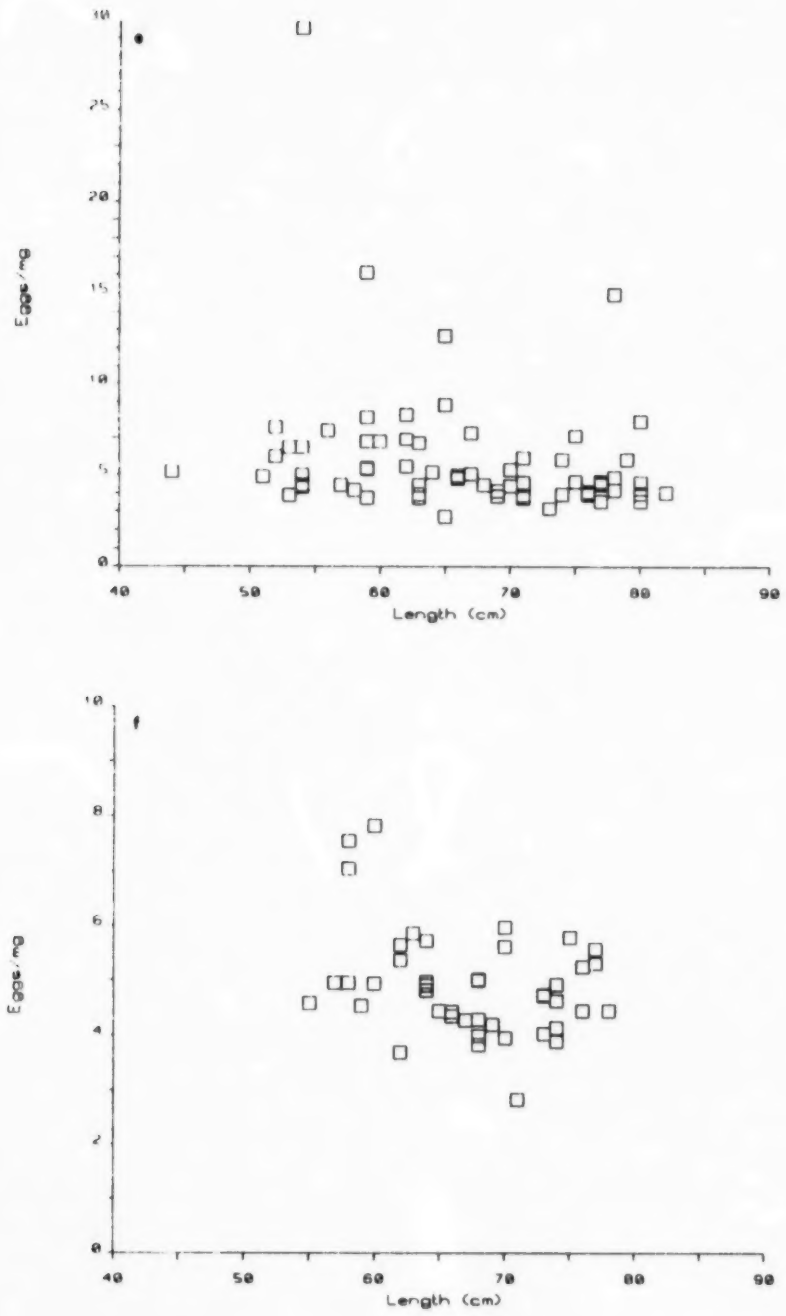


Figure 5. Continued.
e) BLUE WATERS, Hecate Strait, January 30-February 9, 1989.
f) GAIL BERNICE, west coast Vancouver Is., January 29, 1990.

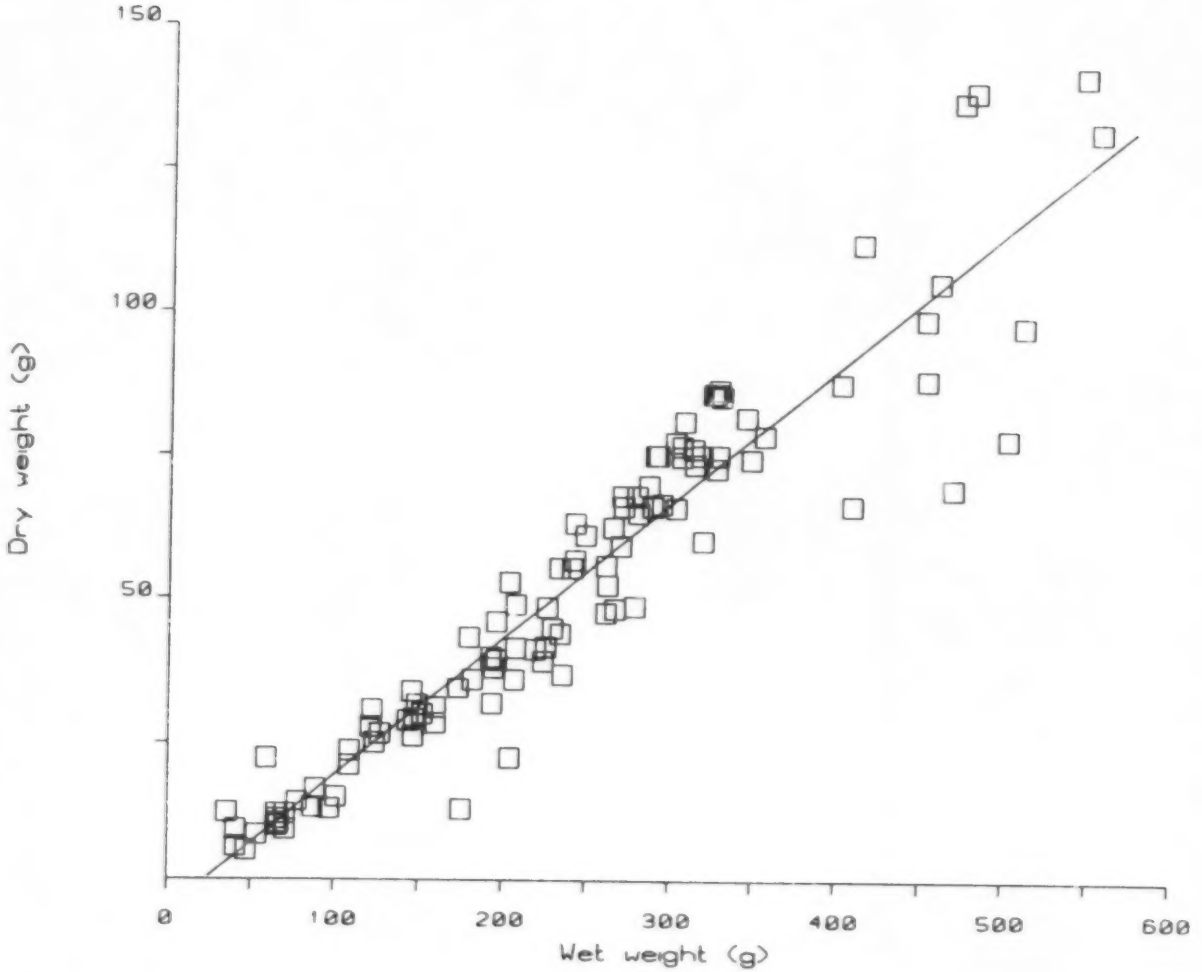


Figure 6. Pacific cod oocyte sample dry weight in g (D) vs wet weight in g (W) for NUCLEUS sample in Hecate Strait, January 5-17, 1987. D = -0.432 + 0.237 W.

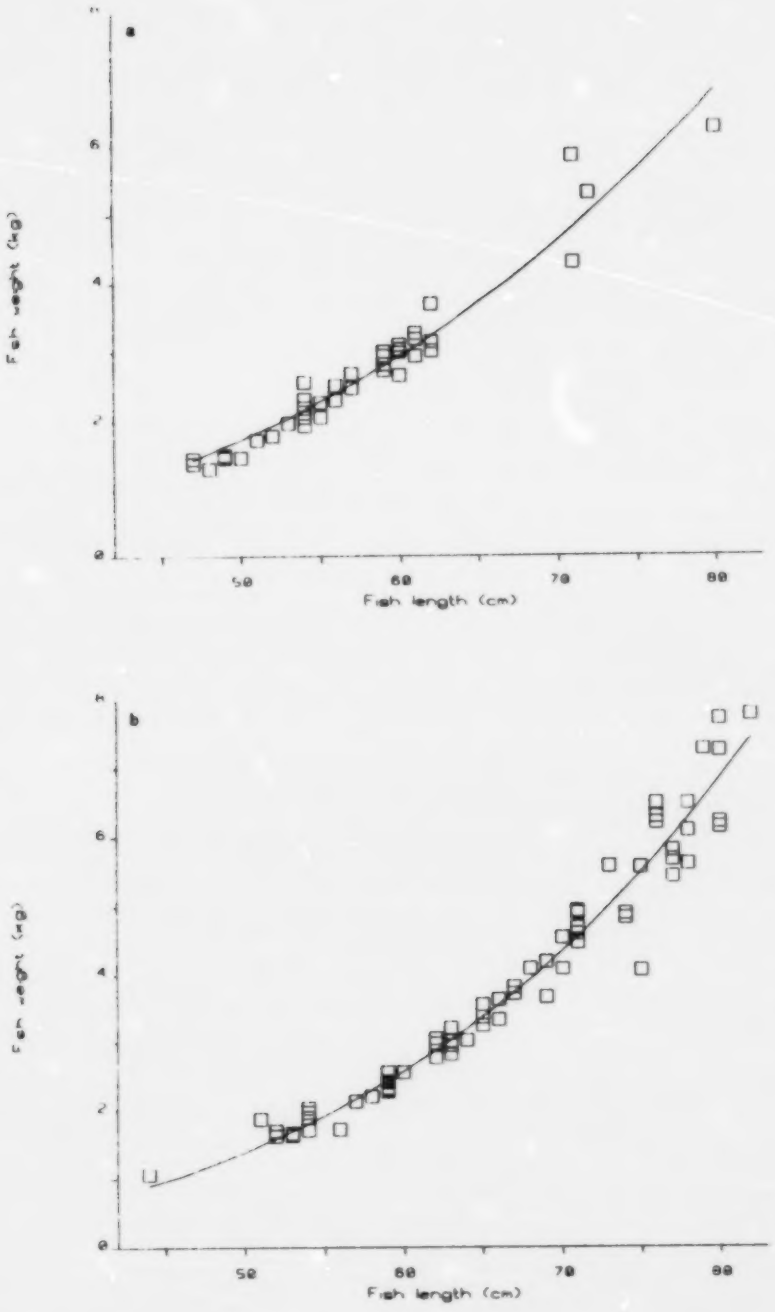


Fig. 7. Pacific cod round weight in kg (W) vs length in cm (L), by sample.
a) DANNY & DAVID, west coast of Vancouver Is., Feb. 5, 1988.
$W = 7.00 \times 10^{-6} L^{3.1614}$
b) BLUE WATERS, Hecate Strait, January 30-February 9, 1989.
$W = 3.86 \times 10^{-6} L^{3.2786}$

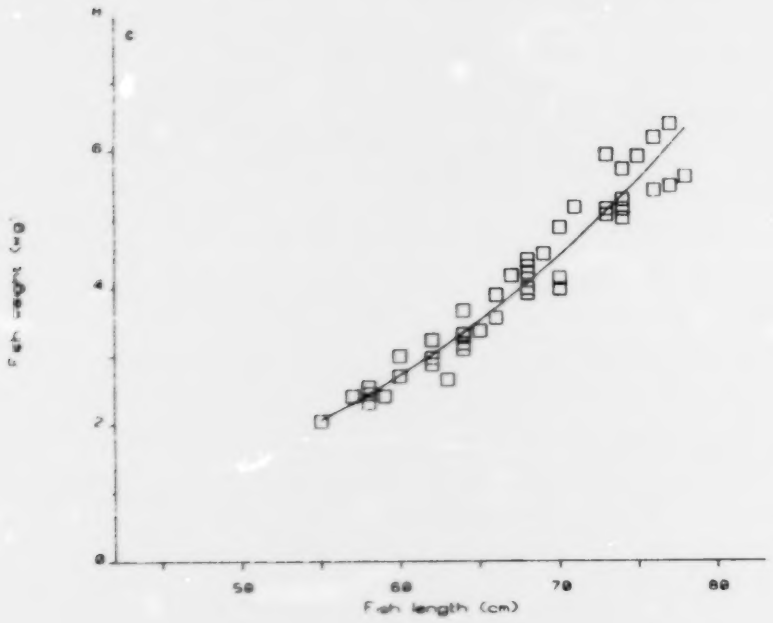


Figure 7. Continued.
c) GAIL BERNICE, west coast of Vancouver Is., Jan. 29, 1990.
$W = 5.24 \times 10^{-6} L^{3.2138}$

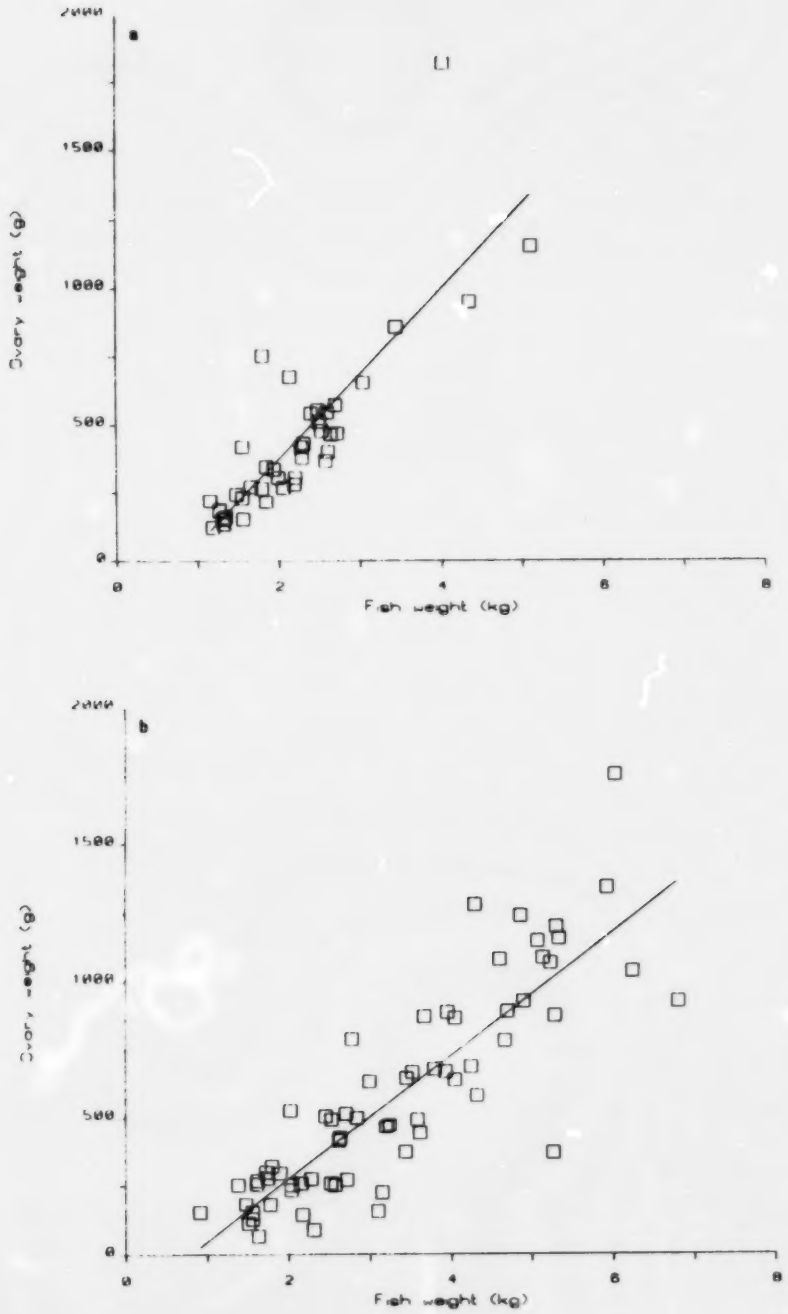


Figure 8. Pacific cod ovary weight in g (O) vs round fish weight in kg (F), by sample.
a) DANNY & DAVID, west coast of Vancouver Is., Feb. 5, 1988.
O = -248 + 311 F; r = 0.84;
b) BLUE WATERS, Hecate Strait, January 30-February 5, 1988.
O = -182 + 227 F; r = 0.86;

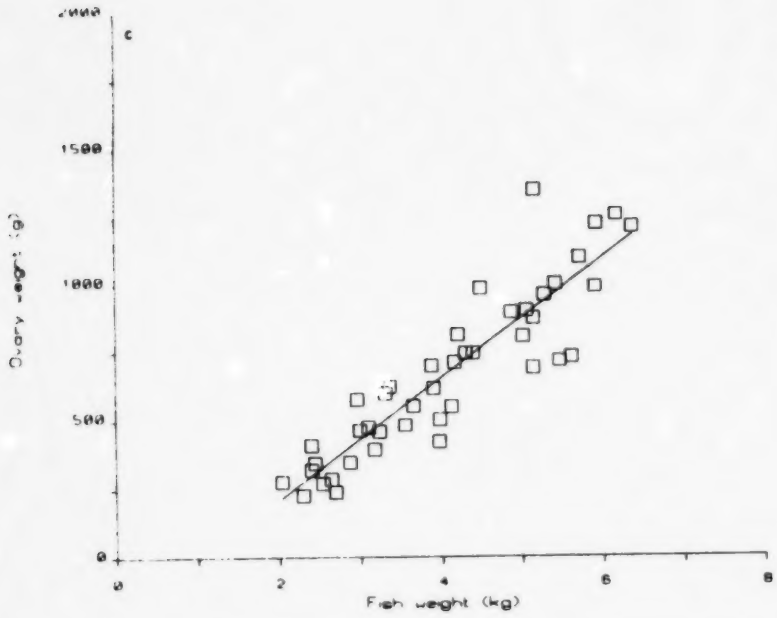


Figure 8. Continued.
c) GAIL BERNICE, west coast of Vancouver Is., Jan. 29, 1990.
O = -239 + 223 F; r = 0.81.

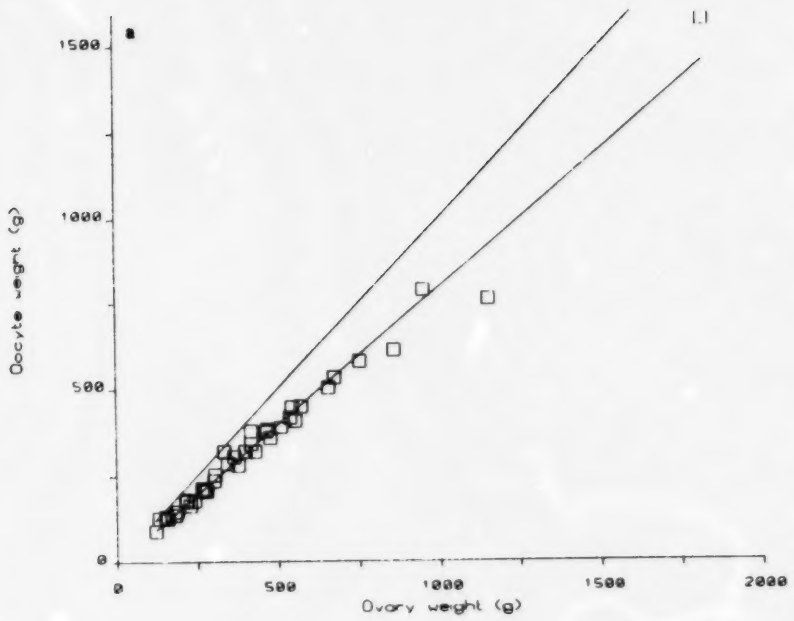


Figure 9. Pacific cod oocyte sample weight in g (C) vs whole ovary weight in g (V), by sample. The extra line in each panel is the line representing equal ovary and oocyte sample weight. The difference (vertical distance) between the two lines represents the weight of ovarian tissue and small, undeveloped oocytes lost during processing.

a) DANNY & DAVID, west coast of Vancouver Is., Feb. 5, 1988.
C = -5.40 + 0.804 V; r = 0.99;

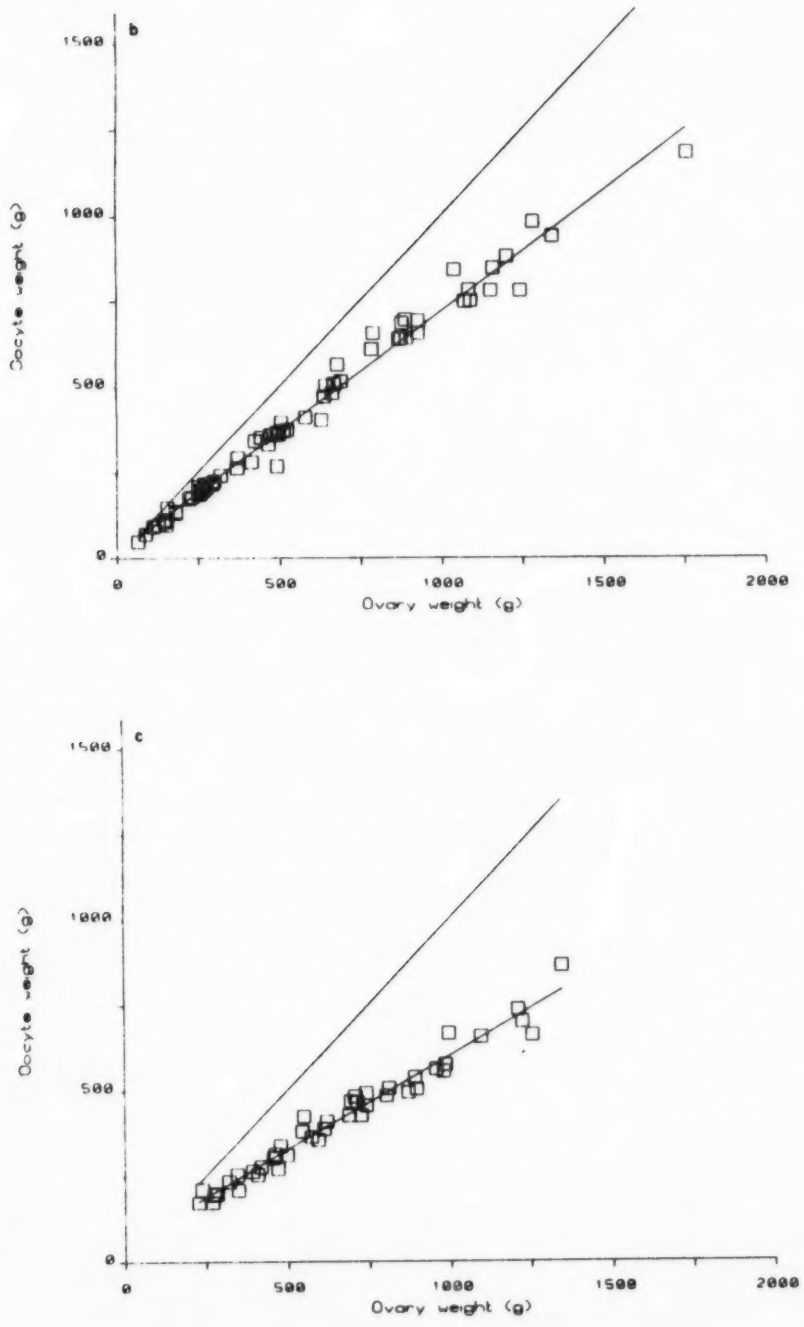


Figure 9. Continued.
b) BLUE WATERS, Hecate Strait, January 30-February 5, 1988.
C = 16.2 + 0.706 V; r = 0.99;
c) GAIL BERNICE, west coast of Vancouver Is., Jan. 29, 1990.
C = 50.5 + 0.550 V; r = 0.98.

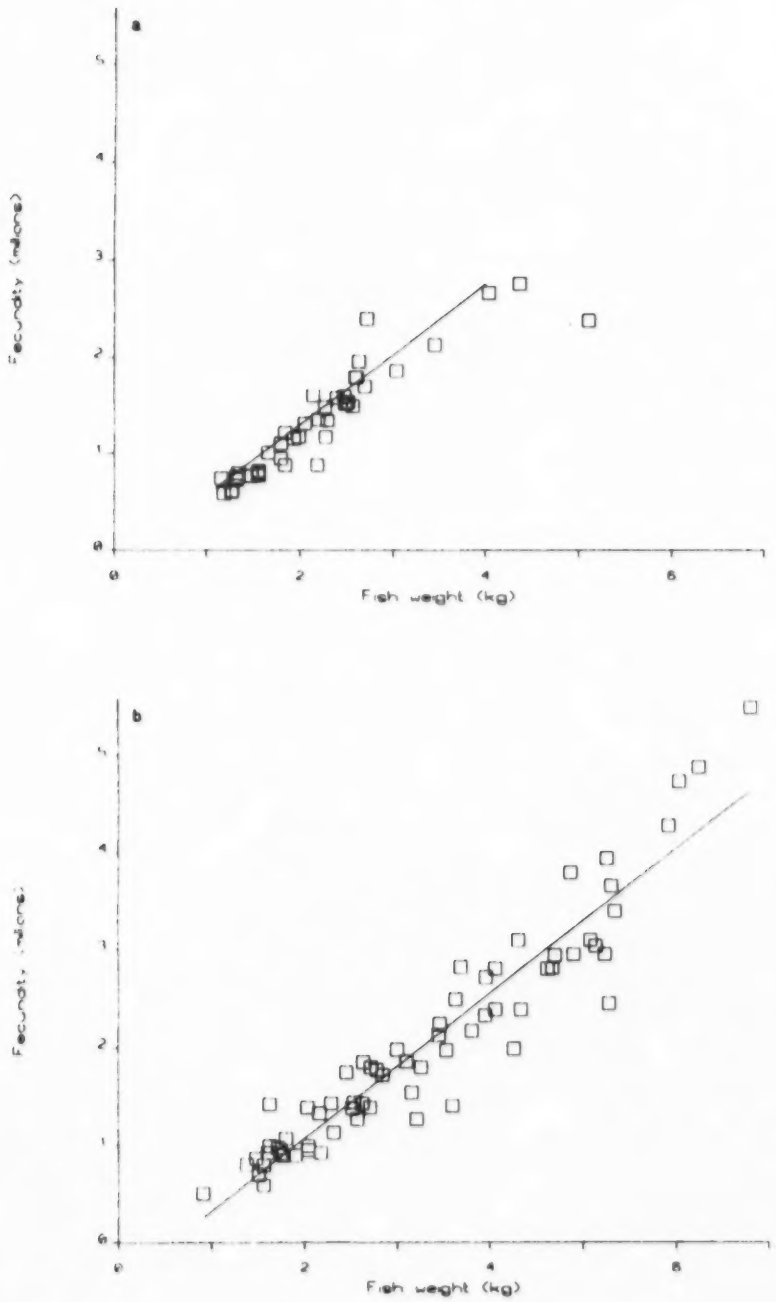


Figure 10. Pacific cod fecundity vs fish weight (less ovaries), by sample.

a) DANNY & DAVID, west coast of Vancouver Is., Feb. 5, 1988.
   F = -0.037 + 0.619 W; r = 0.92;
b) BLUE WATERS, Hecate Strait, January 30-February 5, 1988.
   F = -0.416 + 0.741 W; r = 0.90;

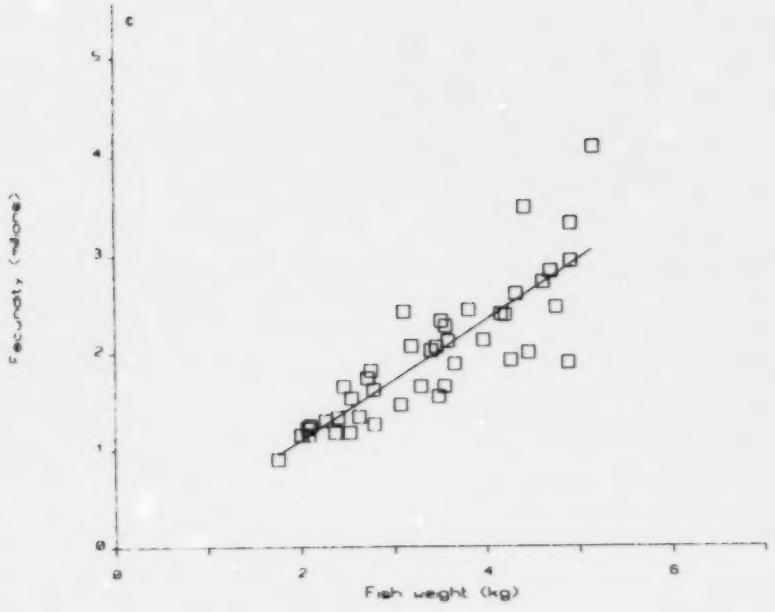


Figure 10. Continued.
c) GAIL BERNICE, west coast of Vancouver Is., Jan. 29, 1990.
F = -0.071 + 0.500 W; r = 0.77.